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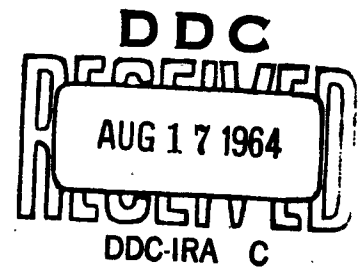
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PROBLEMS PERTINENT TO LOWERING AND RAISING LOADS IN THE OCEAN

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PROBLEMS PERTINENT TO LOWERING AND RAISING LOADS IN THE OCEAN

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by

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ABSTRACT

A survey of literature and specialists indicates there is need for RDT&E in deep ocean load lifting techniques to provide: (1) improved load handling lines of higher strength and durability, (2) improved winches with higher speeds and storage capacities, (3) improved emplacement techniques, (4) better knowledge of the dynamic loadings induced in the load bearing lines particularly by wave action, (5) improved load recovery techniques, especially when ocean bottom "gook" is present.

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OBJECTIVE

The Fiscal Year (FY) 1964 task instructions for Bureau of Yards and Docks (BUDOCKS) Research, Development, Test and Evaluation (RDTE) task Y-F015-01-01, Structures in the deep ocean-subtask-001(b), Mechanics of Placing and Recovering Heavy Loads in the Deep Ocean, are in six parts. Part Number Two is considered as the objective of this Technical Note. It reads:

"....(2) Provide a Technical Note which outlines the problems of lowering and raising heavy loads with recommendations for areas in which research should be conducted...."

The outline nature of this Note is emphasized; treatment of each area in depth is not provided.

INTRODUCTION

The RDT&E of BUDOCKS in handling heavy loads in the deep ocean should be correlated, of course, with overall Navy needs.

It is pertinent that the Deep Submergence System Review Group proposes a 330 million dollar program beginning in FY-65 to develop techniques for rescuing crews and salvaging submarines from the ocean bottom. Under a proposed 5-year program, beginning in FY-65, small air transportable submarines would be developed that would be able to rescue men at 6,000 foot depths and search for submarines at depths as great as 20,000 feet (New York Times News Service, 1964). Present rescue depths are limited to 850 feet.

The raising and lowering of heavy loads would seem a dominant operation under this program. There are likely to be many others, e.g., installation of large Anti-Submarine Warfare (ASW) structures of a civil engineering type, i.e., fixed type structures.

With the exception of relatively light construction of limited scope, e.g., arrays, significant construction to date seems to be restricted to the continental shelf and then to depths no greater than 300 to 400 feet.

The RDT&E areas presented in this Note were obtained by means of (1) a Naval Civil Engineering Laboratory (NCEL) Seminar, at which representatives of five firms of stature gave one-day presentations on construction in the ocean, (2) review of considerable literature, (3) correspondence and conversation with

knowledgeable individuals on a professional and personal basis.

Credits are given in the Acknowledgement and Reference chapters of this Technical Note.

LOAD HANDLING CABLES

Improved cables are required with higher moduli of elasticity than presently available. Flexible cable has the advantage of continuous operations usage combined with relatively compact and easy storage. However, outstanding disadvantages of such cables are: (1) twisting of rope resulting from manufacturing procedures and the resultant necessity to store or maintain the rope under tension at all times, (2) requirement for more than one rope to support heavy loads and the resultant inter-twining of ropes together with unequal load distribution to each rope, and (3) limited lengths of commercially available rope having large diameter (Faires, 1964).

There are likely to be other disadvantages, such as abrasion resulting from relative motion of rope fibers or the introduction of ultra-high strength materials into wire rope fabrication, which might well be included in a research task but not in an engineering investigation.

According to Germeles (1963), Holm (1964), and Carlson (1964), wire rope, though desirable for its high strength and resistance to damage from marine life, is impractical due to its own dead weight which comprises a very significant portion of the static loading of the cable. The maximum length of cable which can hold itself without any factor of safety is only 62,000 feet. Thus, with a desirable safety factor of about 3 to allow for dynamic forces (discussed in later chapters), corrosion, and abrasion, this self-supporting length would be reduced to 20,000 feet. While adequate for self-supporting in most ocean areas, this leaves room for very little payload in the ocean depths of interest. To render use of wire rope practical, introduction of buoyancy in or on the cable would be necessary. An equivalent way of effecting this would be through use of tapered cables. A study of corrosion resistance and a means of raising the elastic limit would also be necessary.

Freeman (1964) feels that synthetic ropes (e.g., plastic) are likely better than wire rope. However, there is still a need to know (1) dominant physical characteristics, e.g., moduli, (2) degree of damage likely from marine life, e.g.,

sharks, (3) fatigue and ultimate strength capacities.

Van Dorn (1964) also suggests that fiber glass ropes seem promising, and although some tests have been run, there is a need for a lot more. Large diameter, e.g., 4-inch, synthetic fiber ropes in a continuously submerged environment need study (Dunham, 1964).

Non-twist ropes, e.g., braided, as are presently being used in some deep ocean work should be further investigated (Lee, 1964).

A feasible RDT&E program might involve: (1) development of a mathematical description of rope twisting in particular rope designs and investigation of alternative designs which minimize the generation of torque associated with changing rope tension and allied effects, (2) development of an experimental facility which enables practical confirmation of mathematical models and at the same time demonstrates the omissions and errors of the theoretical approach, (3) development of model simulation of forces and motions which lead to inter-twining and unequal load distribution in multi-rope suspension systems, and investigation of causes, cures, theory, feedback control, and other problems, (4) investigation of possibilities of radically different rope manufacturing techniques which are not length limited (Faires, 1964).

TUBULAR SUPPORTS

A pipe for lowering and raising loads has the advantage of a strong wall which can displace water and reduce the pipe string water-weight while maintaining strength and hence realizing very large loads to very deep submergence (Faires, 1964).

A pipe has outstanding disadvantages connected with (1) segmented assembly of pipe string leading to very long time for raising and lowering operations, (2) complicated pipe handling and storage, (3) difficult mating of segmented pipe and continuous electrical cable needed for measurement, (4) stiff continuous pipe wall permitting torsional, shear and other vibrational modes and stresses which are noticeably different from the flexible rope situation, (5) a relatively new field of materials such as ultra-high-strength glass fibers, silica fibers, iron fibers combined with a cementing matrix which could also contain electrical wire in the matrix to form continuous pipe length or solid cylinder lengths as substitutes for metal pipe, e.g., steel.

A tubular support research program might involve: (1) development of a mathematical description of pipe and pipe connections to include as many different motions and stresses as possible, (2) development of an experimental model simulation of pipe systems applicable to mathematical descriptions, (3) development of materials for multi-component matrix pipes and solid cylinders designed for high-stress lift operations.

Global Marine Drilling Company of Los Angeles has undertaken some unique operations in lifting and undersea exploration through the use of drill pipes on their specially equipped vessels (Thornburg, et. al., 1964)

DeLong Corporation has used Texas Tower type tubular legged barges as bottom based platforms for heavy construction in water up to 200 feet deep (Tait, 1964).

The force and stress induced in piles by the wave and current need investigation.

The tendency of the pipes to pendulate has been studied analytically by Lampietti (1963). However, there is need for experimental verification of the analytical predictions, especially of the damping values used in the predictions.

LOAD ORIENTATION DEVICES

Loads tend to rotate; this tendency might be reduced by the use of fins.

Propellers might also be used for the purpose; the power and control problem likely is formidable here.

Holm (1964) suggests dual suspension from two ships a given distance apart. However, this would necessitate a greater total length of lines and further complicate bottom positioning. Even then rotation and entanglement may result should an imbalance of cable strains occur.

PRECISION POSITIONING AND EMPLACEMENT TECHNIQUES AND DEVICES

Techniques need to be developed to permit precision positioning of barges and emplacement in a precise pattern of objects on the bottom in deep ocean, e.g., those required to place six structures in 1000 foot diameter circle in 12,000 feet of water. At present none exist (Freeman, 1964).

Although there are many suggestions and certainly many pieces of equipment, e.g., pingers, none of this has been systematized and least of all tested to a satisfactory degree.

The following common systems should have further study: (1) fixed mooring systems, (2) dynamic positioning, (3) relative positioning devices, e.g., pingers on the bottom (Cline and Campbell, 1964).

This effort probably requires more development, test and evaluation, and less research.

MOORING TECHNIQUES AND DEVICES

Light and reliable sea anchors are required. Explosive anchors show promise, but have been tested only in shallow water, e.g., 200 - 300 feet (Freeman, 1964).

Deep water tests of promising concepts are needed.

CHARACTERISTICS OF THE OCEAN BOTTOM

The characteristics of the topography are required, e.g., roughness, slope, and bearing capacity of the soil (Freeman, 1964).

An RDT&E program might include (1) how deep submersibles might be used in surveying, (2) uses for high-resolution sonar, (3) methods for gaining information on the soil-bearing capacity. Such a program may also be of interest to operations such as bottom laid pipelines where trenches are required. (Duvivier, 1964).

STABLE PLATFORM MOTION AND MOORING FORCES

A sound general theoretical-analytical technique is needed.

NCEL established a lead in specific cases with the theoretical study by Kaplan and Putz (1962) and experimental and theoretical studies by O'Brien and Muga (1963 and 1964).

Predictions made by General Electric for the response of the Mohole semi-submersible type platform for Brown and Root were specific, of course, and apparently for regular waves only (Muga, 1964).

A generalization of all that has been done to date is needed to permit prediction of motion and force for a wide variety of platforms, all in irregular seas. In particular, techniques suitable for machine type computation are needed. Those by Lewis (1964) for ships underway are pertinent.

Gerwick (1964) states that while lowering pre-cast bells, cones and shafts, with weights up to 160 tons in shallow water, operations were delayed consistently by tidal current and he found it necessary to make the actual seating of the units in slack time. Also he has not found a way to reduce the lateral motion (surge) of construction barges to a low enough level to permit efficient construction from barges of such things as sewer outfalls. Consequently, fixed underwater platforms, e.g., those of the DeLong type (Texas Towers), are required for such operations.

The interaction between moored platforms, mooring lines, bottom anchors and surface waves, plus internal or thermal waves for situations involving operations in ocean depths greater than 6,000 feet is probably a matter for concern. If there is need for such an operation and the mooring must hold for a long time period, then experimental studies using models at a reasonably large scale, perhaps one to twenty, are usually suggested and are usually rewarding. However, they can be expensive and require special locations, instrumentation, development, considerable thought and planning and probably a great deal of justification. Work of this type should be approached with caution (Faires, 1964).

The Canadian Sea-test range, just north of Puget Sound, would be an excellent location for such an experimental effort. Depths to 1,000 feet and elaborate controls are available.

DYNAMIC LOADS IN CABLES

Main concern is with cables suspended from a floating platform and used to handle heavy submerged loads although mooring cables are also important.

Existing information is limited, e.g., that in Germeles (1963). In the analysis of a single cable used to lower linear array type loads in the deep ocean to 12,000 feet, it is found that very slight periodic motions of the point of attachment of the cable to floating platform, such as that due to platform response to wave action, may result in excessive stresses.

As an example, Germeles uses a 15-ton trussed aluminum linear array suspended on a 1-5/8-inch diameter flexible wire rope. At a vessel motion frequency of 1 radian/second (6.3 seconds/cycle), the maximum safe motion amplitude is 20 feet; at a frequency of 1.5 rad/sec, it is 5.0 feet; while at a frequency of 2.0 rad/sec, it is only 1.7 feet.

The velocity of sound in the cable should be as large as possible. This makes the resonant frequencies high so that they lie on the cut-off edge of the spectrum of a given sea state. Low sound velocities inherent to fiber ropes and some synthetic ropes render them unfavorable in this respect. Hence, considerable research and testing is necessary in these areas.

Lateral forces in cables, particularly in mooring cables, also need to be investigated.

DESIRABLE LOAD SHAPES

A proper structure may have an improper shape. Covers could be designed to totally encase certain structures so as to improve their handling when submerged, e.g., reduce their tendency to drift and decrease drag on them.

On the other hand, arrays with a large dynamic mass greatly increase the dynamic stresses, especially near resonance. Entrainment or displacement of large amounts of water increases the dynamic mass of the array. Therefore, the array should preferably be a trussed open structure (Germeles, 1963).

Free fall of loads should be studied. This would require a consideration of permissible terminal velocities.

WINCHES

Improvements to existing types are required so as to permit (1) handling of larger volumes of line (2) more precise metering of load depths (3) higher speeds (4) increased braking reliability (5) greater resistance to sudden starts and stops (6) greater load capacity (Kent, 1964) and (7) better control of tension (Snyder, et.al., 1964).

Advanced type winches should be considered. One termed "Hydrodynamic Winch" has been proposed by the Naval Electronics Laboratory and studied briefly by NCEL.

It is in the form of a floating cylinder which, for loads of the order of 5,000 tons, would be about 200 feet long and 60 feet in diameter. It is controllable in roll by means of pumps. Thus, it can be caused to roll clockwise and counterclockwise at will, so that, through cables wrapped around the periphery of the cylinder, loads fastened to the cables can be raised and lowered.

Preliminary study in the office by NCEL indicates that the Winch is feasible (O'Brien and Budroe, 1964). Consideration should be given to building and testing a small version, e.g., one to handle 100 tons.

BUOYANCY AND DAMPING DEVICES

Pontoons, especially those of the collapsible type, e.g., rubber containers, have already been developed to an appreciable degree for use in routine salvage operations; however, further RDT&E is needed for the adaption of similar pontoons to lifting and lowering operations in the deep ocean (Holm, 1964).

An integral system of inflation and deflation devices is needed to control rates of ascent and descent as well as to maintain proper trim, especially when multi-pontoon configurations are employed. For example, the decrease in pressure when ascending to the surface from 10,000 feet would necessitate the release of 56 volumes of gas to maintain constant displacement and hence a uniform rate of ascent. Any mishap in trim conditions could result in loss of the load.

Damping discs or the equivalent are needed toward reducing the tendency of the loads to jerk and also toward definitely defining the extent of damping as an aid in design.

The production of buoyancy by alternative methods, e.g., chemical, is another possible area of study.

A further more remote possibility is the concept of a manned, free-floating submersible which includes designed buoyant force variations through density control combined with vertical propeller-provided lift (Faires, 1964).

COUPLING AND UNCOUPLING DEVICES

Means for coupling and uncoupling lifting devices to loads needs study, e.g., cables to loads; pipes to loads; pon-

toons to loads and to each other.

Devices could range from magnetic and vacuum types through mechanical types actuated remotely as with television sets.

Coupling and uncoupling is obviously an important part of the load handling operation.

BEHAVIOR OF LOADS IN UNFAVORABLE OCEAN BOTTOM CONDITIONS

Geographical limitations for a particular site location may occasionally demand emplacement of a structure in unsatisfactory load bearing soils such as oozes, mud, clays and silts. Bodies falling or being lowered to the bottom of the ocean or being removed therefrom may pass through layers of this partially consolidated sediment of various concentrations, ranging from liquid to a near solid state. The rheological characteristics of these materials must include most, if not all, types of non-Newtonian behavior, e.g., plastic, pseudo-plastic, dilatant, thixotropic (Robertson, 1964).

There is very little information available concerning the behavior of objects moving through non-Newtonian fluids in general, even in non-ocean environments.

An RDT&E program in this area should begin with studies in the laboratory.

LIKELY IMPACT FORCES

The study of impact forces is related to many of the other RDT&E areas, e.g., load orientation devices; characteristics of the ocean bottom; stable platform motion; dynamic loads in cables; winches.

However, an engineering type study of a given complex is needed to predict impact forces and, if improper, to revise the setup toward improvement. The final requirement is a procedure which allows the prediction of impact forces for any given complex. Such a study might indicate over-design as well as under-design.

EQUIPMENT STRENGTH AND RELIABILITY

Study of strength and reliability as effected by the following should be considered: (1) peak overloads (2) wear considerations (3) fatigue (4) component failure (5) corrosion

(6) age (Kent, 1964).

A study of extreme values is required here. Perhaps this important part of the study might be considered as a separate effort.

MOVEMENT OF QUASI BUOYANT OBJECTS OVER OCEAN BOTTOM

A load in such a condition might tend to bounce, skid, and roll over the ocean bottom in a dangerous manner so as to make placement and recovery difficult.

ANCHORS

Anchors in clay are considered to be well-covered (Kaufman, 1964). This is not the case for those in sand.

Perhaps study under controlled conditions of the laboratory is the best way to start.

Grouted-in-rock chain anchors also need study (Dunham, 1964).

EFFECT OF PRESSURE ON VISCOSITY

Little information is presently available as to the effects of pressure on fluid viscosity. However, experiments with some oils have shown that at pressures equivalent to that found in 33,000 feet of water, viscosity was nearly three times its value at one atmosphere. Similar effects may also occur for sea water when considering pressure at depths of 20,000 feet. This phenomenon could be studied in the laboratory.

A CONSTRUCTION EXERCISE

A full-scale construction exercise should be carried out in which such variables as lowering line tensions, load rotation, translation and acceleration, and precision of emplacement would be measured. These measurements would be analyzed in an effort to formulate a procedure for predicting such tensions and movements in a given case.

The material under Stable Platform Motion and Mooring Forces in this Note is pertinent.

The Canadian test range north of Puget Sound would be a good place for this exercise. The area off NCEL might also be considered. The French diving saucer could be used.

WORK-WAVE RELATIONSHIPS ON CONSTRUCTION TYPE PLATFORMS

This is a traditional suggestion from NCEL through many years; it is still to be implemented.

Consideration should be given to defining the maximum sea state in which personnel and equipment could operate satisfactorily. There is some information on the subject for near shore operations (Glenn, 1950), but none seems to exist for deep sea operations.

Experimental studies in the laboratory using platforms with controlled six-degrees of freedom are required.

The crux of the matter is the permissible wave height and period (Abecasis, 1964, also Trans. Permanent International Association of Navigational Congresses, 1961).

CONCLUSIONS

1. The need for improved lines is dominant. This need is accentuated by the potentially dangerous dynamic forces induced in heavily loaded lines by floating platform motion; hence, there is a need to keep this motion to a minimum.

2. The need for improved winches is second only to that for improved lines. Those with high speed and capacity are needed especially.

3. Improvements in precision of placement are of high importance with related needs for improved: (1) load orientation devices and shapes (2) mooring and coupling techniques and equipment (3) stable platforms, anchors, and winches, and damping devices.

4. Equipment strength and reliability needs improvement, not only against transient loadings, such as quick winch and platform motions and even load breakaway, but also against extremes in long-term effects, such as corrosion and fatigue.

5. Although not dominant, there is need for deliberate study of construction operations particularly as they pertain to load handling.

This can be done experimentally by a controlled construction exercise in the ocean, followed by meaningful analysis of data collected during such an exercise.

6. Site selection should attempt to avoid location of

structures in unsatisfactory ocean bottoms, e.g., those with muds, oozes, and silts. However, the structures may have to be located in such environments due to tactical and strategic requirements. There is, therefore, a need to study load emplacement and especially recovery techniques in these environments.

RECOMMENDATIONS

It is recommended that RDT&E be considered in the following areas:

1. Improved load handling lines. This should include not only improvements to existing lines, but also an investigation of new materials for the manufacture of lines and of means for reducing twisting and inter-twining of lines.
2. Improved winches. This should include not only improvement of existing types but also the development of "far-out" concepts for lifting very heavy loads, e.g., those of the order of 5,000 tons.
3. Improved emplacement techniques. This should include study of the effect of load shape on fall characteristics.
4. Dynamic loads in heavily loaded lines suspended from floating platforms.
5. Improvements in load recovery techniques. This should include study of the movement of a load through muds, oozes, and silts of the ocean bottom.

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